A STUDY OF *VARANUS FLAVESCENS* (HARDWICKE & GRAY) (SAURIA: VARANIDAE)[1]

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(With ten text-figures)

The present study documents several aspects of the biology of *Varanus flavescens*. Adequate available material now makes possible a more detailed description of the morphological features of this species than was previously possible. The annual reproductive and abdominal fat cycles are outlined and the common prey organisms identified. The primary habitat is shown to be mesic to hydric wet savannas and marshlands. The geographic range is defined and the suggestion made that though the species is widely distributed in the Indo-Gangetic Plain, it tends to be spotty. These and other factors lead the authors to consider this the most endangered of all Asian mainland monitors.

INTRODUCTION

This study was undertaken because of all varanid species of mainland Asia, *Varanus flavescens* is one of the poorest known. It is, in addition, surrounded with considerable controversy and mis-information.

The following data were obtained from 1984 through most of 1987, in Bangladesh, India and Pakistan. Additionally, important museum specimens were examined in these countries as well as in Europe and the United States. Total field time was approximately 18 months (India 10, Pakistan 7, Bangladesh 1). Data were obtained from 185 specimens (134 in museums and 51 in the field). All measurements of total length (TOL), tail length (TL) and snout-vent length (SVL) were made to the closest mm; all internal measurements (testes, ova, etc.) were made to the closest 0.1 mm; all weights to the closest 0.1 g.

SYSTEMATICS

Synonomy: Because of the confusion on the part of some biologists concerning the current valid name for this species, the following annotated synonymy of previous name combinations used for this species is provided.

Varanus flavescens (Hardwicke & Gray)

1827: *Monitor flavescens* Hardwicke and Gray, p. 226, type locality "India". First species description.

1830: *Varanus russellii* Heyden (in Ruppell), p. 23, type locality Bengal. First reference to any locality at the provincial level.

1836: *Varanus picquotii* Dumeril and Bibron, p. 485, pl. 35, fig. 5, type locality Bengal.

1838: *Empagusia flavescens* Gray, p. 393. first use of *Empagusia* (now used as a subgenus, Mertens 1942).

1844: *Monitor exanthematicus indicus* Schlegel (not *Tupinambis indicus* Daudin 1802), p. X, type locality Bengal. First association with the African species *Varanus exanthematicus*.

1847: *Varanus flavescens* Cantor, p. 634. First use of the current valid name combination.

1942: *Varanus (Empagusia) flavescens* Mertens, p. 347, pls. 1, 16, figs. 4, 110. First use of *Empagusia* as a subgenus.

For reasons given below the type locality is here restricted to Calcutta, West Bengal, India, to replace "India" as used by the original describers Hardwicke and Gray (1827).

Phylogeny: *Varanus flavescens* is characterized among other features by the fact that its external nares are slit-like in shape, located closer to the tip of the snout than to the eyes (Fig. 1), with a skull that is high in proportion to its length (Fig. 1) and with body scales relatively large when
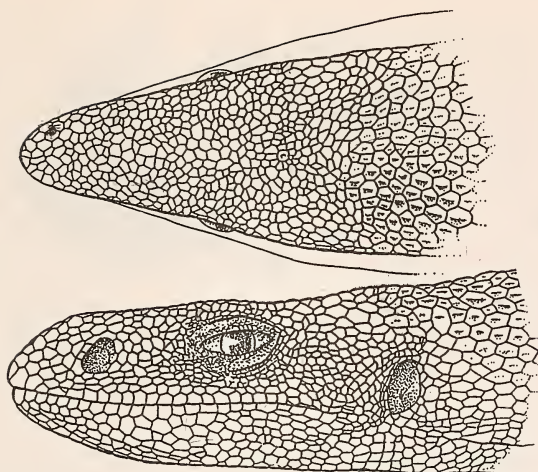
Fig. 1. **Head shape and scalation in** *Varanus flavescens,* **Dokri, Larkana District, Sind Province, Pakistan.**

compared to those of most other monitors. This combination of characters is found in the African savanna monitor *Varanus exanthematicus* (Bosc), leading to Schegel's conclusion that *V. flavescens* (as *Monitor indicus*) was a subspecies of *V. exanthematicus*. This concept of probable close relationship was furthered by Gray's placement of both species in the genus *Empagusia*, erected specially to receive these two species with similar characterstics (though the nostril of *V. exanthematicus* is located much closer to the eye). In 1942 Mertens also concluded these two species were closely related on the basis of skull and jaw structure (particularly the form of the skull and the length height index of the maxillary). He placed both species in the subgenus *Empagusia* – one of seven he established at that time. In 1959 he redescribed the skull of *V. flavescens* on the basis of better material then at hand, adding other characters to those he formerly believed showed relationship to *V. exanthematicus* (supratemporal process of the parietal and the basipterygoid process). He also noted several characters by which these species differed from one another and suggested that *V. flavescens* was the more primitive type from which *V. exanthematicus* evolved.

The studies of Singh *et al.* (1970) introduced new diagnostic characters for *V. flavescens* in which chromosomal morphology played a major role in defining relationships. However, the limited number of species compared and the absence of details important in comparison of *V. flavescens* with other varanid species (ill-defined centromere location and poor resolution) limited the usefulness of these new data in determining the phyletic position of this species. King and King (1975) improved the utility of such data by employing both short-term leucocyte culturing techniques on whole blood and better staining procedures. This resulted in higher resolution and precise centromere location. Their examination of 16 of the 32 congeners showed that these could be placed in six distinct karyotype groups. Not all of these corresponded to current taxonomic groupings. Among these differences were the species *V. exanthematicus* and *V. flavescens*, which failed to assort themselves into a single group. The former was suggested as being more closely related to *V. niloticus* (continental Africa) than to *V. flavescens*, which was closer to its sympatric congener *V. bengalensis*. These studies thus cast considerable doubt on the validity of the subgenus *Empagusia* as currently recognized and suggested that further work was needed before the phyletic relationships of *V. flavescens* could be ascertained. The studies by Holmes, *et al.* (1975) on comparative electrophoretic data tended to substantiate the groupings suggested by the work of King and King on chromosomal morphology, though *V. flavescens* was not included in their list of species examined. However, the study provided additional substantive data to the developing notion that the Mertensian system of varanid relationships may be somewhat incorrect.

Even more recently, Bohme (1982) and Branch (1982) independently concluded that *V. flavescens* and *V. exanthematicus* are only distantly related on the basis of hemipenial morphology. The penial morphology of *V. flavescens* was shown to be more primitive than that of *V. exanthematicus*.

Collectively, the conclusions resulting from this recent work are: 1) the earlier contention of monophyly among living varanids is still valid, 2) *V. salvator* possessed less derived (i.e. more

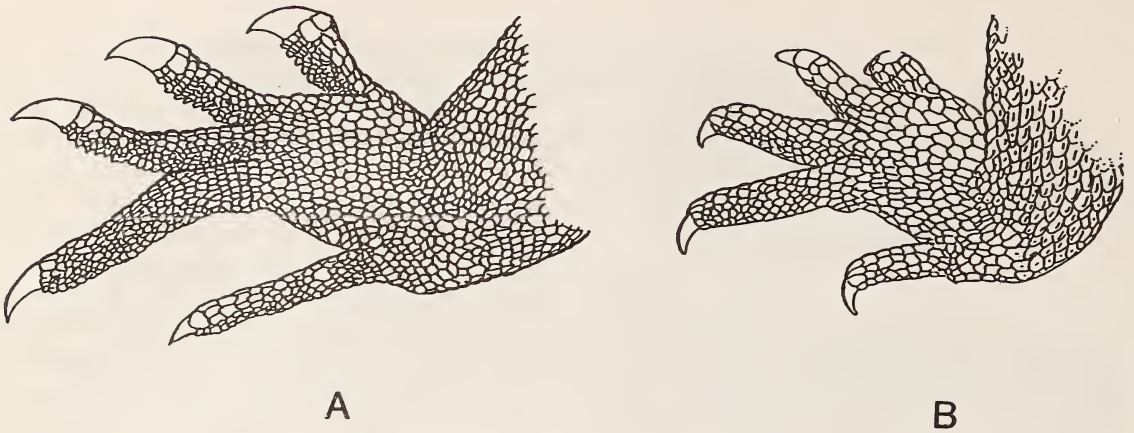A   B

Fig. 2. Hind feet of varanid lizards. A, *V. bengalensis*; B, *V. flavescens*.

primitive) characters than all other species, 3) interspecific relationships among the species included in the genus are less clear than previously believed, 4) while some subgeneric groupings are easily diagnosed on the basis of chromosomes, proteins and morphology, others are not, 5) *V. flavescens* is not as closely related to *V. exanthematicus* as once thought, and that what characters are similar are probably due to convergence, 6) this species is a fairly primitive one, with closest relationships to *V. bengalensis, V. rudicollis, V. salvator* and (by extension, see Auffenberg 1987) *V. olivaceous*. However, the skull shape and construction (which led Mertens to place it close to *V. exanthematicus* to begin with), short, stubby toes (Fig. 2, found only in *V. griseus* among other mainland Asian species) and certain parasitic relationships and behavioural traits (see below) suggest that it should continue to receive separate nomenclatorial status at the subgeneric level. Thus we favour the retention of the subgeneric concept as applied to *V. flavescens*, placing it (by priority) in *Empagusia* as its sole member. It is very likely that additional study of other characters will throw other light on its relations to other *Varanus* species and that a thorough cladistic approach to the problem of varanid phylogeny would yield new and important insights into this matter.

MORPHOLOGY

A description of the skull anatomy and scalation of *Varanus flavescens* is provided by Mertens (1942, 1959), though based on only 7 specimens, of which only three are provided with locality data (all West Bengal, India). Thus the many additional specimens now available from several widely scattered localities and which we have examined during the course of this study suggest we address the matter of potentially significant geographic, sexual and ontogenetic variation in this species. Of these, the most cogent pertain to scalation, bodily proportions and colour pattern. Some of the variation has been the basis for mis-identification of *V. bengalensis* as *V. flavescens* in the past. (Biswas and Kar have transposed the photographs and legends for *V. flavescens* and *V. salvator*).

The following descriptions and discussion are based on 185 specimens.

Size and Mass: Compared to other Asian monitor species, *Varanus flavescens* is a rather small species, (only *V. griseus* has a smalller average adult size; W.A. notes). In spite of the fact that we examined a large number of individuals in the field and in museums, the specimen cited by Boulenger (1885) is still the largest reported (TOL 920 mm, SVL 410, TL 510). Visser (1985) reports a newly hatched young with TOL 145 mm, SVL 66, TL 79; those neonates examined by us in the field (all from India) varied from TOL 143–
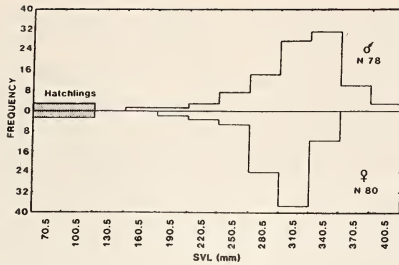
Fig. 3. Frequency of size classes in *V. flavescens,* all localities combined.

188 mm, SVL 64–92, TL 78–96; means of all hatchlings for which such data are available (N 18) are $\bar{X}$ TOL 163.3 mm, $\bar{X}$ SVL 77.6, $\bar{X}$ TL 85.7. Mean TOL for all non-hatchlings (N 167) is 699.5 mm, $\bar{X}$ SVL 315.1, $\bar{X}$ TL 384.4. There is no significant difference between size of individuals in populations from the Ganges (N 50) and Indus (N 117) river valleys. Tail length is relatively short when compared to other monitor species, varying from 1.2–1.3 times the SVL ($\bar{X}$ 1.27), with the relationship being linear and expressed by the formula tail length = 1.27^x SVL– 18.55 ($R^2 = 0.83$). There is no significant change in proportionate tail length with age, as in some other monitor species (Mertens 1942, Auffenberg 1982). There is slight, but significant difference in mean SVL (Fig. 3) of males (342.0 mm, N=55) and females (332.2 mm, N = 47) ($t = 2.88$, DF 100, p > 0.02). The small difference is rather unusual in varanids, for in almost all species studied males are significantly larger than females. This fact must be of considerable importance in *V. flavescens* reproductive behaviour, for in the courtship of all other varanids studied (Auffenberg 1983, 1987), the larger males of those species tend to completely dominate the smaller females. The fact that both sexes of *V. flavescens* are similar in size suggests that their reproductive behaviour may be quite different from that reported for other *Varanus* species. We assume that male dominant behaviour is less marked in this species during courtship. This may, in turn, be related to the

seasonal change in body coloration during the reproductive season of adults (see below).

The weight of 83 adult individuals varied from 510 to 1040 g, $\bar{X}$ = 768.5 g (SD$^\pm$ 154.6, V = 20.1); no weights are yet available for hatchlings. **Proportions:** That the tail length does not change ontogenetically in length in proportion to the body and head (SVL) has been shown above.

The slit-shaped nostril is placed closer to the snout than to the eye (Fig. 1) with the ratio of snout-nostril length/snout to ear (anterior edge) length varying from 0.21 to 0.28, $\bar{X}$ = 0.25. We find no significant geographic or ontogenetic variation in nostril position.

The toes of particularly the hind feet of this species are short and the claws relatively straight (both mentioned by Mertens 1942) when compared to congeners (except *V. griseus*) (Fig. 2). Its short toes were noted as early as 1884 by Murray, who called this species the "short-toed water lizard". The length of the hind foot along the longest toe (number IV) is usually 14 percent of the SVL in individuals of all sizes. Toe IV of the congeneric *V. bengalensis* is much longer (Fig. 2). **Viscera:** The absence of a caecum at the beginning of the large intestine is a common feature of faunivorous invertebrates (Hladik 1976). It is essentially completely missing in the carnivorous *V. salvator* (Auffenberg 1987), only very slightly developed in the largely insectivorous *V. bengalensis* (Auffenberg MS) and very well developed in the frugo-molluscovore *V. olivaceus* (Auffenberg 1987). In other vertebrate animals a caecum is often associated with herbivory. Thus we were quite surprised to find a somewhat enlarged area at the anterior end of the large intestine, supplied with abundant blood vessels that could be described as a developed caecal pouch. Why this should occur in a completely faunivorous varanid (see below) remains unknown.

Calculation of the internal surface area (A = 2 pi rh) of the stomach, small and large intestine of *V. flavescens* (following the techniques suggested by Chivers and Hladik 1980) shows that the surface area of the stomach is the greatest of the three

intestinal sections (7854.0 mm^2), as expected in a carnivore (Hladik 1976). The large intestine is the next largest (6141.8 mm^2), and the small intestine possesses the least surface area. The area of the stomach surface and that of the large intestine relative to the area of the small intestine provides a quantitative index of gut differentiation (Coef. Gut Diff.: stomach area + large intestine area/small intestine area; see Chivers and Hladik 1980 for justification, etc.). In *V. flavescens* the area index is 2.79. This value is higher than those values obtained for the only other varanids studied (Auffenberg 1987; values 2.24 and 2.42 for *V. olivaceus* and *V. salvator* respectively). The larger value in *V. flavescens* is primarily due to the proportionately smaller small intestine. Since most absorption takes place in this part of the gut (on the basis of its rich blood vessel supply), we assume that the food of this species must be nutritionally rich and probably much more easily digested than that of the other two species studied previously, which have proportionately longer small intestines.

The liver of 100 individuals was weighed and this compared to total animal weight for different months of the year. The results show that there is no difference in liver weight in males and females, but a significant seasonal change in which liver weight is low in August and September, but high in December through April. The latter months are those of least activity on the part of the lizards and the former are the months following courtship and breeding and during the monsoon. During the monsoon (mid-July through mid-September, depending on locality), liver weight varies from 1.4 to 3.4 % of total body weight (N 31); during the winter (December through March) liver weight varies from 3.3 to 7.7 % (N 34). The mean liver weights for these periods ($\overline{X}$ = 2.6, SD 0.7, and $\overline{X}$ = 4.6, SD 1.1 respectively) are significantly different at the 0.001 % level (t = 129.2, df 70).

As far as is known, liver function in reptiles is probably identical to that in mammals. Its main roles are concerned with protein, cholesterol and bile salt synthesis, glycogen storage, and metabolism of steroid hormones. From a dietary standpoint, the liver is most important in fat degradation and detoxification of a number of proteinaceous substances. In general, larger livers have been viewed to result from greater systematic levels of hepatotoxins and greater variation in chemicals being metabolized (see Freeland and Janzen 1974, Swain 1976, for general reviews). However, the pattern of seasonal liver weight variation in *V. flavescens* suggests that glycogen storage may also be a major factor in liver size. During the monsoon, food is, in general, the most abundant in the entire year, but this is also the time of greatest activity; winter is the time of least activity.

While seasonal differences in liver weight may be due largely to glycogen storage, interspecies weight differences may be related to dietary differences. In *V. flavescens*, the liver is a large organ, being on average 3.3 % of the total body weight. This compares to only 1.9 % in *V. olivaceus* and 2.6 % in *V. salvator* (Auffenberg 1987). Differences between these and *V. flavescens* are significant at the 0.02 % level (df = 271). In *V. bengalensis* mean liver weight is 2.3 % of total weight, and in *V. griseus* 2.9 %. Differences between these species and *V. flavescens* are not statistically significant (t = 55.8, df 46; t = 38.6, df 116 respectively. Thus the data gathered so far on proportionate liver weight of varanids suggests that the highly selective frugo-molluscovore *V. olivaceus* is much less exposed to high toxin levels than the generalist carnivore species such as *V. flavescens* (see below).

One of the major distinguishing features of this species is the oval nostril that is placed closer to the tip of the snout than to the eye (in *V. salvator* it is rounded, near the snout tip; in *V. griseus* it is slit-like and very close to the eye, and in *V. bengalensis* it is slit-like and placed about midway between the snout tip and the eye). The distance between the snout tip and anterior edge of the nostril in *V. flavescens* goes into the distance from the snout tip to the anterior edge of the tympanum opening from 3.50 to 5.49 times, with a mean of 4.35 (SD 0.41). Fig.1 shows the normal shape of the nostril and its position in respect to the various

parts of the head. The same illustration also shows the characteristic shape of the head of this species in side view. With the exception of *V. exanthematicus*, *V. flavescens* has the highest skull in proportion to its length than any of its congeners. In addition, the lower jaw is generally more robust than in the other species.

Visceral Fat: In all lizards in which fat deposits have been studied (see Fox 1977), accumulation of fat in the tail is always indicative of high food abundance. However, fat bodies in the visceral area have been associated with both food supply and reproduction. Volsoe (1944) suggested that visceral fat served as a food reserve in the snake *Vipera berus*. Presst (1971) and Bellairs (1970) extended this to all snakes, pointing out that seasonally small fat bodies were correlated with food shortages. However, in lizards the correlation between fat body size and food abundance is less clear. Hahn and Tinkle (1965), plus several other authors that have followed them, showed that in at least some female iguanid lizards visceral fat is important in follicular development. Bellairs (1970) and Burrage (1975) have suggested that visceral fat may be used by the developing embryos in some lizard species. To complicate matters even more, Fox (1977) demonstrated that seasonal breeders have fat bodies, while year-round breeders do not. However, a study of ten sympatric skink species in tropical evergreen forests of the Philippines suggests a less definite association with annual breeding pattern and a better correlation with seasonal food abundance within the microhabitats of each of the species studied (Auffenberg and Auffenberg 1987). Not all female lizards possess visceral fat bodies, and none of the current explanations clarify the presence of such bodies in males, suggesting that several factors may be responsible for their presence, absence, or seasonal size in lizards.

Visceral fat bodies have been demonstrated in several varanid species (see Auffenberg 1987 for review), but extensively studied in only a few. The general conclusion is that all varanids possess such bodies. This study shows that adult *Varanus flavescens* have them. However, they are very small or absent in all individuals less than 200 mm SVL (0– 0.2 % of total body weight). Thus, extensive body fat deposition (which varies seasonally) is a characteristic of adults only (suggesting a reproductive importance).

In adult *V. flavescens* these deposits may comprise as much as 16.9 % of the total body weight during at least part of the year (OR 0.15–10.9 %). The mean fat weight of all adult specimens examined (N = 70) is 3.8, SD 2.5 % of total weight. This is a greater amount than has been demonstrated for any varanid species studied so far (Auffenberg 1987). *V. flavescens* also occurs in the most seasonally variable environment of any species studied so far (see below).

There is no clear relationship between adult total weight and fat weight ($R^2 = 0.58$), due largely to the considerable variation of fat present. This variation has both an individual and seasonal component, though the latter is dominant. Fig.4 shows that the pattern of seasonal variation in fat weight is identical in male and female adult individuals. The highest values (corrected for adult weight) are found from about December through March in both sexes ($\overline{X} = 5.97$ % of total body weight). From April to about June proportionate fat weight is reduced. The lowest levels occur from July through October ($\overline{X} = 1.08$ %). During November there is a dramatic increase in the amount of visceral fat accumulated, leading to the · high winter levels.

The values for males and females are nearly identical for almost all months. Thus the pattern differs from that in *V. olivaceus*, in which males have significantly more fat than females during some months (Auffenberg 1987). Since an identical annual pattern with identical values occurs in males as well as females, we assume that abdominal fat deposition in *V. flavescens* is not related to the yolking of ova (as in some iguanids at least), but is probably related to seasonal food abundance (as has been suggested in other varanids; Auffenberg 1987). The period of low fat weight in *V. flavescens* (Pakistan and northern India populations) from July through October occurs during the monsoon in this part of the species
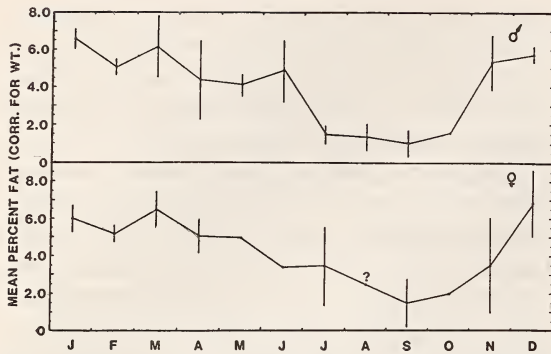
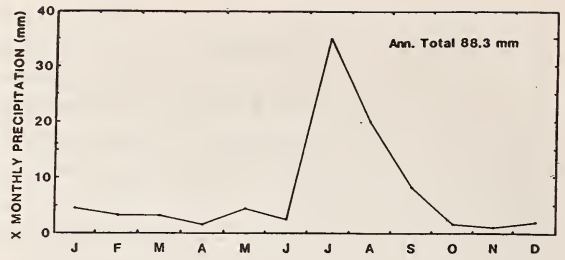Fig. 4. Annual pattern of visceral fat in adult male and female *V. flavescens* from Dokri, Pakistan.

Fig. 5. Monthly precipitation in Larkana District, Pakistan. Estimated totals extrapolated from data provided by Pakistan meteriological Dept.

range, when extensive flooding is an annual occurrence in the river flood plain marshlands where this monitor species is most common (see below). Fig.5 shows the annual rainfall pattern near the Dokri (Pakistan) *V. flavescens* population.

Scalation: Very few data are available on the scale characters of this species. The availability of a large number of specimens from throughout the species range suggests we take this opportunity to tabulate those scale characters in *V. flavescens* which are known to be of importance in defining this and other Asian monitor lizard species Several earlier authors have drawn attention to the much larger and heavily keeled scales of *V. flavescens* when compared to those of the other species of the Indian subcontinent. This is easily seen particularly on the dorsal surface. Keeled scales also occur on the dorsal surfaces of both hind and front legs, extending to near the feet (Fig. 2). Scales around the midbody vary from 84 to 104, $\overline{X}$ 95.5 (SD 4.3). The ventral longitudinal scales from the gular fold to the insertion of the hind limb vary from 68 to 85, $\overline{X}$ (Pakistan) 75.1 (SD 3.9). In general, the head scales are rather small when compared to most congeners. There are no enlarged supraoculars as occur in *V. bengalensis* from the eastern parts of its range (= *V. b. nebulosus*). The number of scales from the angle of the mouth on one side to the angle on the other side range from 42 to 53, mean 48.5 (SD 2.8); infralabials 23 to 31, $\overline{X}$ 25.5 (SD 2.5) and suboculars three to four, usually the former. Head

scalation is shown in Fig.1.

COLOUR

As in most *Varanus* species, hatchling *Varanus flavescens* are more vividly coloured than the adults. In general, they are easily distinguished from those of *V. griseus* by having transverse rows of fused yellow spots on a dark background, rather than a few dark bands on a distinctly light-coloured background; *V. salvator* hatchlings have transverse bands of separated yellow ocelli; and those of *V. bengalensis* usually have transverse bands of separated yellowish ocelli and small black dots on a brownish background. Visser (1985) provides a coloured photograph of a hatchling *V. flavescens*.

Adult *V. flavescens* are often confused with adult *V. bengalensis*. This is due largely to the great variation in colour and pattern found in the former. Even within a single population, there is considerable variation among adults of more or less equal size (Fig. 6). While the fused light transverse bars on the body are always present, they vary in transverse length (1–23 scales, X 5.57) and number between the front and hind legs (5–10, $\overline{X}$ 7.38). The background colour and pattern is even more variable. It may be uniformly black (rare), or the black pigment may form a reticulate pattern, often with a central dot, forming large (often faint) ocelli over much of the body. When little melanin is present the ground colour may be dark to light brown, with only the
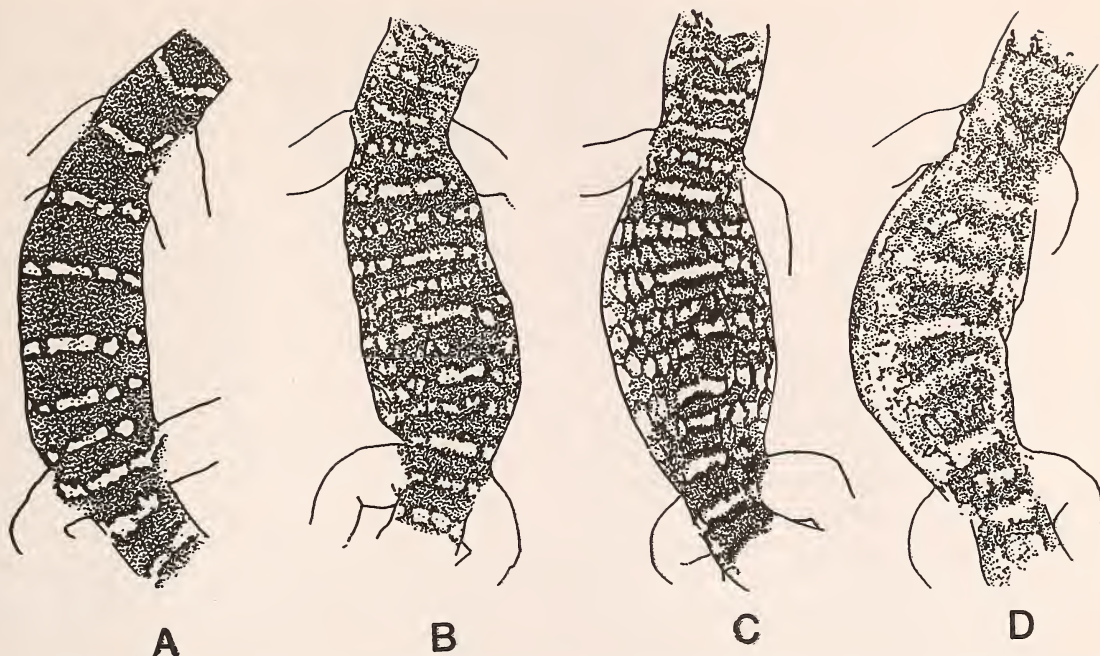
Fig. 6. Pattern variation in adult *V. flavescens* from Dokri Pakistan, based on transparencies. A, W.A. field no. 148/87; B W.A. 51/87; C, W.A. 109/87; D, W.A. 114/87.

transverse bands of fused yellow spots edged in black. Many individuals have a suffusion of brownish red to deep red mid-dorsally between the yellow transverse markings and the dark body bands may be suffused with brick red to orange (somewhat seasonal, see below). These lateral dark bands continue onto the ventral surface, though they never meet at the midline. The throat is almost always provided with several black, posteriorly directed V's. In certain seasons the throat may be suffused with yellow to orange. No other Asian monitor lizards possess any orange to red colour on the dorsal or ventral body surfaces.

d'Abreu (1932) reported that adult colour of *Varanus flavescens* from Bihar changed seasonally, the darker body bands purportedly becoming brick red during the monsoon season. Until this study, no material representing appropriate seasonal coverage was available to verify his statements. We were able to examine a minimum of five adult individuals each month during an entire year from a single population at Dokri, Sind Province, Pakistan. This enabled us to establish the type and degree of seasonal colour change occurring in this species. Our conclusions are that colour changes of the type described by d'Abreu (1) do occur, (2) in adults (only) of both sexes, and (3) in populations (probably all) outside of Bihar, India.

These results were based on defining each specimen as possessing one of three categories of orange-red suffusion on the body (0 none, 1 slight, 2 considerable). Analysis of these data show that an intermediate category of orange-red colour suffusion occurs in at least some individuals most months of the year (range in character state 0.09–1.86). The least suffusion is found in October (0.09), following egg laying in females and testes size decrease in September. During most of the remainder of the year the suffusion remains near the mean value of 0.75. However, concomitant with increase in testes size and the beginning of follicular ripening, there is a dramatic increase in the pigment (both sexes) from April to May

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TABLE 1

SIZE (MM) AND WEIGHT (G) OF OVARIAN FOLLICLES AND OVARY (ONE ONLY)
IN *Varanus Flavescens* (DOKRI, PAKISTAN POPULATION)

	XN ova	Follicle Dia. (mm)[1]		Ovary Wt. (g)	
	<4 mm	X	OR	X	OR
Jan.	0	None	None	0.6	0.5–0.7
Feb.	0	None	None	0.9	0.6–1.0
Mar.	0	None	None	0.7	0.5–1.0
Apr.	0	None	None	0.7	0.5–0.9
May	6.1	4.7	<4.0–6.2	0.9	
Jun.	15.0	4.8	<4.0–6.4	1.0	0.6–1.3
Jul.	25.3	5.7	<4.0–10.8	2.1	3.0–6.3
Aug.	18.2	9.5	<4.0–15.5	14.8	0.4–48.0
Sep.	22.6	9.2	<4.0–15.0	8.6	0.2–31.9
Oct.	10.3	8.9	<4.0–10.6	3.7	0.2–40.0
Nov.	13.1	5.6	<4.0–6.1	0.7	0.1–1.3
Dec.	6.3	None	None	0.6	0.6–0.6

[1] Only follicles greater or equal to 4 mm diameter.

(1.86). This remains high through June and July (1.80 for both months), thence dropping regularly through August and September to the lowest values of the year in October again. Individuals that are not sexually mature lack this seasonal colour change. Thus the suffusion is definitely correlated with the development of seasonally important reproductive tissues in mature individuals of both sexes and probably under hormonal control. *Varanus flavescens* is the only species of monitor lizard in which a seasonal colour change has been demonstrated.

REPRODUCTION

Compared to that for many other lizard families, information on varanid reproduction is scanty. While none of the reproductive data gathered for *Varanus flavescens* are considered complete, the combination of field observations, discussions with local commercial hunters and dissection of a significant number of specimens has provided an ample information base from at which at least the broad outlines of this species reproductive biology can be deduced.

Sexual Maturity: The testes weight, length, diameter and volume (estimated from formula for an ovoid) were determined for all individuals of *V. flavescens* dissected. These data show that males less than 260 mm SVL are rarely sexually mature. Enlarged, eventually yolked ova, corpora lutea and ovarian follicles greater than 5 mm occur only in females with SVL over 250 mm and a weight of about 300 g. Females in this reproductive stage represent 85 % of the total female sample during the breeding season. The smallest female that either laid eggs in captivity or had eggs in the oviduct was 295 mm SVL. The minimum SVL of females at maturity is 61 percent of the greatest size recorded in the female sample. This is more or less equivalent to the same statistic in *V. olivaceus* (74 %), but considerably more than in giant *V. komodoensis* (30 %) (data from Auffenberg 1981, 1987). This suggests that growth is maintained for a shorter period of time after sexual maturity in *V. flavescens* than for those few varanid species for which such data are currently available.

In vitro staining of the bones of six individuals with tetracycline (see Hutton 1986 for technique description) shows that both females and males of *V. flavescens* become sexually mature during their third year of life. Visser (1985) reports that hatch

lings raised in captivity under optimum feeding conditions became sexually mature in three and a half years. This compares favourably with data for *V. bengalensis* in the same geographic area (Auffenberg notes) and is intermediate between the smallest varanid species (mature at end of first year, King and Rhodes 1982), and the largest (*V. komodoensis*, 5–6 years. Auffenberg 1981).

Female Reproductive Cycle: To date, the only complete studies of the female reproductive cycle of varanid lizards is that on *Varanus bengalensis* in northern India by Jacob and Ramaswami (1976) and on *V. olivaceus* in the Philippine Islands (Auffenberg 1987). Both investigations suggest that most females lay a single clutch of eggs each year; the current study on *V. flavescens* suggests the same.

Variation in mean monthly volume of female reproductive tissues in *V. flavescens* (one ovary only, Table 1) reflects the progress of follicular development and ovulation. Ovarian tissue volumes are least from November through May (regressed, phase), followed by a dramatic increase in June through July, due largely to yolk deposition. Ovarian tissue volume remains high during August, but drops in September, when undeveloped follicles begin to deteriorate. This volume is slightly increased November to December, when new follicles enlarge, beginning the annual cycle of the following year. The ovarian weight of females examined after completion of vitellogenesis, but before oviposition, is about eight times as great in those females that had oviposited but not yet initiated growth of the next follicle crop. Corpora lutea, formed in the ovary after ovulation, are bright orange-yellow and flattened, with a longitudinal groove on one side. Early in the cycle, those follicles that develop into yolked ova exhibit a colour change from translucent milky-white to pale yellow, becoming more distinctly yellow as more yolk is accumulated. Each ovum weighs about 5 g when ovulated and has a diameter of about 20 mm. One female was preserved just during ovulation, with 10 ova still in the ovary, four already having been received into the oviducts (2+2). The oviductal
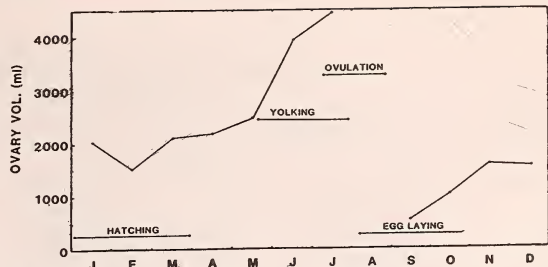

Fig. 7. The annual pattern of changing ovary volume in adult female *V. flavescens* from Dokri, Pakistan. Timing of the other major phases of the reproductive cycle are also shown.

infundibulae were greatly expanded to receive the ova released from the ovaries, but we saw no evidence that it had stretched over the ovary, as has been claimed for some lizards.

The earliest and latest dates for shelled oviductal and oviposited eggs in our study (freshly caught females) are 2 August and 7 October. Visser (1985) reports oviposition in a captive female in a European zoo on 21 July—very close to the earliest date we record in the wild.

During the resting stage the oviductal chamber is straight and parallel-sided. However, at the height of the reproductive cycle it becomes thick-walled, convoluted, and develops the enlarged infundibulum mentioned above. The day following oviposition the oviduct is distinctly stretched in those areas where the shelled eggs were located previously, and where the tissue remains much deeper pink than adjacent oviductal tissues. Most mature females retain evidence of stretched oviductal regions until at least December.

The ovarian follicles of each female dissected were measured. Monthly averages and ranges are shown in Table 1. The trend obviously follows that of ovarian volumes, for yolk deposition in the ova is the greatest contributor to this weight. Though yolking occurs in some ova as early as March, the most significant increase in both number of follicles involved and percent of weight gain occurs just before ovulation (usually July, see Fig. 7), so that there is no clear separation between the vitellogenic and ovulatory phases of the reproductive cycle.

Fig. 7 depicts the progress of vitellogenesis in the Pakistani population examined. Because the

TABLE 2

SEASONAL VARIATION IN SIZE (MM) AND WEIGHT (G) OF TESTES IN
Varanus flavescens (DOKRI, PAKISTAN POPULATION)

		Diameter		Length		Weight	
	N	X	OR	X	OR	X	OR
Jan.	3	7.9	5.1-9.8	17.1	15.5-20.4	0.3	0.3-0.4
Feb.	1	6.8		15.1		0.4	
Mar.	6	7.9	4.4-11.8	16.3	11.1-21.7	0.4	0.3-0.6
Apr.	4	7.6	5.5-9.8	18.7	15.1-21.5	0.3	0.2-0.4
May	5	14.0	13.0-15.9	25.7	19.1-37.1	2.4	1.9-3.0
Jun.	3	12.7	12.0-13.0	22.6	18.9-25.5	1.7	1.0-2.1
Jul.	3	14.7	14.4-15.1	25.0	23.7-25.9	2.7	2.5-3.0
Aug.	4	11.6	8.2-13.6	21.4	18.7-24.1	1.3	0.5-2.0
Sep.	13	5.5	4.2-8.2	12.9	9.3-17.7	0.4	0.2-0.6
Oct.	4	6.8	5.6-8.6	14.2	12.0-18.0	0.2	0.2-0.3
Nov.	12	7.2	6.0-8.4	17.8	16.0-18.4	0.3	0.1-0.5
Dec.	3	8.7	7.1-9.7	14.3	11.5-15.8	0.3	0.3-0.3
N	61	X 9.3		X 18.4		X 0.9	

climate is so similar throughout the rather limited distribution of this species, we believe that this summary reflects the reproductive cycle throughout the entire range of this species.

All eggs oviposited by freshly caught individuals (3 clutches) were laid during the course of a single day. Visser (1985) reports that in captivity his female laid eggs at a rate of about one per hour, but believes that the entire oviposition behaviour of this female may have been abnormal. We agree, for the rate at which our specimens laid their eggs was much higher. Considered on an annual basis, egg laying in *V. flavescens* occurs during a relatively short period * three months maximum. An analysis of the weight of ab-

dominal fat bodies in this species also reflects a single annual cycle. This is important in the context of possible use of abdominal fat reserves during the vitellogenic process.

Very few data are available on the size of the annual reproductive female cohort in varanid lizards. For *Varanus olivaceus* (Auffenberg 1987) it is estimated that 90 percent of all mature females lay eggs each year. For the Pakistan adult females of *V. flavescens* we estimate this statistic as about 52 percent (though 100% of the small August sample were gravid).

MALE REPRODUCTIVE CYCLE

Few data are available regarding seasonal testicular changes in varanid lizards. Testes enlargement during the breeding season has been reported for *Varanus bengalensis* (Upadhyay and Gukaya 1972), *V. griseus* (Kehl and Combescot 1955) and *V. olivaceus* (Auffenberg 1987). The same pattern is now demonstrable for *V. flavescens*.

Average testicular volume is lowest from September through February (Fig. 8, Table 2). It increases from March to the annual peak in June and July. In August the weight drops rapidly to
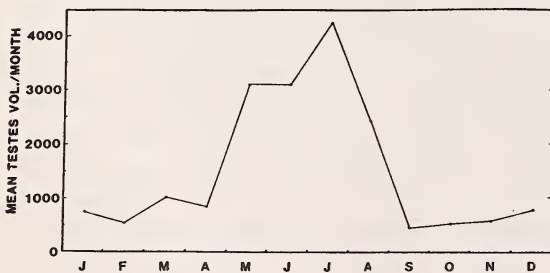

Fig. 8. Annual pattern of mean testes volume in adult *V. flavescens* from Dokri, Pakistan.

TABLE 3

EGG MORPHOMETRICS OF *Varanus Flavescens* (ALL LOCALITIES COMBINED)

Clutch No	Diameter (mm)		Length (mm)		Weight (g)		No of Eggs
	X	OR	X	OR	X	OR	
1	19.0	18.1-21.3	39.5	34.8-43.2	10.7	0.2-11.6	18
2	22.0	20.5-22.5	36.0	34.4-37.0	11.1	0.4-11.9	14
3	21.8	20.5-22.5	37.1	36.4-37.8	10.4	0.0-11.4	6
4	21.2	20.3-23.0	37.3	35.2-38.1	10.8	0.2-11.8	6
5	21.5	20.5-22.5	35.7	34.4-37.0	10.5	0.1-11.5	4
X	21.0		37.1		10.7		
SD	1.2		1.5		0.3		

the lowest level of the entire year. Mean testicular weight data show the same seasonal pattern, so that testes mass and volume are largest during June and July — the presumed courtship period. This is the time of year when Visser (1985) noted courtship and breeding in his captives in Europe as well. Testes colour also changes seasonally. The usually greyish white testes become distinctly yellowish during the height of the reproductive period.

SEX RATIO

Seasonal proportional representation of males and females captured/examined was also analyzed. This shows that the overall annual sex ratio is slightly in favour of males (57%). This is due to the fact that males are significantly more common than females from May through July ($\overline{X}$ 76.7% of the total monthly samples for these three months). During the remaining nine months the sex ratio is 1:1 (mean male proportion 51%). This increase in number of males taken during the courtship period and that immediately preceding it has been demonstrated in several species of skinks (Auffenberg and Auffenberg 1987) and is particularly noted in *Varanus bengalnesis* (W.A. notes). As in *V. bengalensis*, the mature females of *V. flavescens* are predominant during the height of the breeding period (July males of *V. flavescens*, 43%).

EGG MORPHOMETRICS, COMPLEMENT AND HATCHING

The eggs of all varanid species have a soft, relatively smooth, leathery shell, without surface ornamental or crystalline material. While the eggs of some species adhere to one another in one or more masses, those of *V. flavescens* are always separate.

Eighty eggs of *Varanus flavescens* were measured and weighed (Table 3). Mean and over-all range in length, diameter and weight are 37.1 mm (34.4–43.2), 21 mm (18.1–23.0) and 10.7 g (10.0–11.8). The average total mass of the entire complement is 282.6 g, or 42.2 % of the average mature female total weight $\overline{X} = 768.5g$, N 86).

Based on the number of eggs laid in captivity and the evidence from the oviductal chambers of females that had already oviposited, the number of eggs per clutch varies from four to thirty ($\overline{X} = 16.0$, SD 10.2). This agrees fairly well with the number of developed ovarian eggs ovulated annually, as evidenced by the number of corpora lutea counted in the ovaries ($\overline{X} = 11.7$, SD 6.45). Though sample size is small, clutch size is probably positively related to female size, as has been demonstrated for *V. olivaceus* (Auffenberg 1987).

No data are available on nest construction or site selection in *Varanus flavescens*. Visser (1985) has shown that incubation time in this species is 149–155 days at an incubation temperature of 30°C. The direct correlation between annual rainfall pattern (i.e. the arrival of annual monsoon rains) and the reproductive pattern of the

species (and *V. griseus* and *V. bengalensis* in the same geographic range, W.A. notes) suggests that this is the single most important factor in reproductive cycling of *V. flavescens*. If the incubation time reported in captive animals by Visser also holds under field conditions (which is likely, given a mean soil temperature of 28.3° C during the developmental period; data from this study), young would be injected into the local ecosystem from December through February. This is a cool period throughout the northern parts of this species range, when adults are definitely more or less inactive. Thus it is highly unlikely that neonates of this species would be very active either. In India, hatchlings were found in the field from March to July, suggesting that while development may be completed in five months, emergence from the nest may be delayed by a further one to four months. The March sightings (West Bengal) come from the more eastern parts of the species range, where monsoon rains come early, and the July dates (Uttar Pradesh) from areas where the monsoon arrives much later. Delayed emergence (in the field), has been shown to be dependant on local rainfall in other monitor species (see Auffenberg 1987, for review).

GEOGRAPHIC DISTRIBUTION

Because of the poor representation of this species in museum collections, the several important mis-identifications with *Varanus bengalensis* in the past, and the new information gathered during this study, we list all those localities from which definitely identified *V. flavescens* are now known. The list is based on specimens examined in museums, collected or observed in the field during the course of this study, figured in the literature, or otherwise described in terms that leave no doubt as to the correct identification.

Bangladesh: Dinajpur District, Parbatipur (d' Abreu 1932); Madhupur, Mymensingh Dist. and Salna village, Dacca Dist. (Whitaker & Hitada 1981). Faridpur District, Madaripur (this study); Dhaka District, Narayanganj this study).

India: *Assam:* Gauhati Dist., Gauhati (Indian Museum); Dhuburi Dist., Goalpara (=Golpara)

(Smith 1932).

West Bengal: Terai Dist., Shiliguri (=Silliguri, Chicago Museum Natural History); Calcutta Dist., Calcutta (Indian Museum and Vienna Natural History Museum), Calcutta Botanical Gardens (Indian Museum); Sagar Island, Pathar Pratina (Indian Museum); Krishnagar Distr., Krishnagar (Indian Museum); 24 Parganas Dist., Pepouldo and Melanchar Thana (Chicago Natural History Museum); Kakdwip (this study); Hoogley Dist., Singui Thana (Chicago Natural History Museum); Medinipur Dist., 20 km NW Kharagpur (Sights 1949), Medinipur (= Midnapur, Smith 1932);

Orissa: Balsor Dist., Serogatrth, 8 km E Nilgiri (indian Museum, Biswas & Kar 1982, and this study); Cuttack Dist., Nandan Kanan (Indian Museum), Bhitarkanika, Dangmal (Biswas & Kar 1982); Barang Dist.,NE Nandan Kanan Biological Park (Biswas & Kar 1982)

Bihar: Patna Dist., Patna (d'Abreau 1932 and this sudy); Saran Dist. (Smith 19332), 4 km SW Chhapra (this study); District ?, Gordon Hill (locality not found) (Mertens 1959 b); Bettiah Dist., 20 km NW Bettiah (this study); Pargani Dist., Pakaur (= Pakur, Smoith 1932).

Uttar Pradesh: Gorakpur Dist., Gorakpur (Indian Museum); Fatehgarh Dist., 10 km SE Fatehgarh (this study); Varanasi Dist., 21 km SE. Varanasi (this study); Mirzapur Dist., 10 km W. Mirzapur (this study); Agra Dist., Agra (Anderson, 1871, Indian Museum); 5 km N. Dayal Bagh (this study); Gaziabad Dist., 23 km S. New Delhi (sight record only, this study).

Haryana: Amballa Dist., Amballa (Smith 1932, reporting on specimen in Indian Museum, confirmed during this study, see below).

Nepal: 'Nepal', no further data, reported first by Canton 1849 and later by Boulenger 1885 (based on specimens [confirmed during this study] in the British Museum); Chitwan (Gurung 1983, US National Museum); Arun River vvalley, Sagarnatha National Park (R. Jackson, *in litt.*).

Pakistan: *Sind Prov:* ''Sind'' (Murray 1884); Larkana Distr., Dokri (Mertens 1942, reporting on specimens in Senckenberg Museum, confirmed in

this study, Florida State Museum, and Zoological Survey Pakistan); Dadu Dist., Dadu (this study).

Northwest Frontier Prov.: Peshwar Dist., Sholgara Village, near Charsadda (Zoological Survey Pakistan). 'Dir and Swwat', no definite localities (McMahon 1901).

Punjab Prov.: (Jhelum Dist., near Dina (Zoological Survey Pakistan); Sargodha Dist., near Laya (collections previously made by professional hunters, but not confirmed during this study); and Lahore Dist. (?), near Pindi Bhatian (same comment as previous record).

All of the definite localities listed above are along, or near major rivers, of which the Brahmaputra, Ganges, and Indus are the major ones. In Orissa, India, they are also known from the drainage systems of the Brahmani and Mahanadi rivers. In these stream valleys *V. flavescens* extends along major tributaries to the foot of mountainous regions–even the base of the Mt. Everest complex–but not into the highlands above the tropical zone. Thus the distributional pattern is almost identical to that of *Gavialis gangeticus* and other typical Indo-Gangetic Plain species (including the Orissa river systems mentioned).

On the basis of geography and local environment, we expect that *V. flavescens* will eventually be found in Arunachal Pradesh in India, along the Dihang and Lohit river valleys. In Nepal the species probably occurs mainly along the southern border and posssibly restricted to the floodplains of the Arun river in the southeast and the Girwa river in the southwest, both or which are tributaries of the Ganges, along which the species is locally common.

The following localities are definitely in error, most based on mis-identifications of *V. bengalensis* (or *V. dumerilii* in a few cases) as *V. flavescens*, or records from illogical environments or geography on the basis of what is now known about the species (see below for habitat details).

"Penang", first reported by Cantor (1847), and followed by Gunther (1864), Murray (1884), Flower (1896, 1899) and Boulenger (1912). All Malaysian records (listed here) were denied by Smedley (1932), with which we agree.

"Malay Peninsula", a generalized distributional statement, perhaps based on Cantor's "Penang" record (1847), first listed as Malay Peninsula by Boulenger (1885) and followed by Boulenger (1890), Flower (1896, 1899), Boulenger (1912) and Flower (1929); see comments above regarding "Penang".

"Trang", Thailand, mentioned only by Boulenger (1912). *V. flavescens* does not occur in this area on basis of field work by Auffenberg (field notes, 1974).

"Concan and Deccan", in south and central India, reported by Murray (1884), on no valid basis as far as we can determine. The species does not occur there. (Auffenberg field work, 1979, 1984- 5).

"Baluchistan", Pakistan, Murray (1884), undoubtedly based on misidentification with *V. bengalensis* for *V. flavescens* does not occur there on the basis of absence of appropriate habitat.

"Indochina", first reported by Tirant (1885), followed by Mocquard (1906), undoubtedly based on misidentification with *V. bengalensis*. No voucher specimens available anywhere.

"Pegu and Mergui", Burma, mentioned as a *possibility* on basis of material in hand by Theobald (in Mason, 1882), and followed by Murray (1884), Boulenger (1885, 1890, 1912), Flower (1896, 1899, 1929), and Annandale (1905). No voucher specimens available from Burma.

"Ceylon", listed by Murray (1884), is undoubtedly based on misidentification with *V. bengalensis*.

"Nurpore (= Nurpur), Salt Range", Punjab, Pakistan, first reported by Hora and Chopra (1923) and followed by Smith (1932). This record is certainly based on a *V. bengalensis*, as most of the environment is probably inappropriate for *V. flavescens* though *V. bengalensis* is locally common.

"Padang, Sumatra" mentioned by Holtzinger —Tenever is clearly incorrect, but interesting because of the importance of this locality in the distributional pattern of *V. bengalensis*

"Kutch", Gujarat Prov., India, (Murray 1884) is possibly correct. Throughout its long history,

the Indus river has been notably vagrant, exhibiting extraordinary wanderings and mutations of its course in response to natural and man-induced environmental changes. The major change in the delta region is the westward drift of the major distributaries. Not too many thousands of years ago these emptied into what is now the Rann of Kutch (see Holmes 1968, Flam 1986) — a broad, level expanse of largely saline mudflats that tend to become flooded each year due to monsoon winds. While *V. flavescens* is not known to occur in brackish water situations (see below), it has been collected very close to the sea at Sagar Island, West Bengal. Since some of the flooding in the Rann is due to freshwater inundation from Sind, Pakistan, and because appropriate habitats for this species might occur along these seasonal distributaries in the interior of the nearby country, Murray's old record of this species from Kutch may be correct. However, *V. bengalensis* (with which Murray clearly confused *V. flavescens* in other instances) is common in the Rann of Katcch area (W.A. field notes). Appropriate habitats for *V. flavescens* occur in marshlands north of Bhavnagar, Gujrat, and along the lower reaches of the Sabarmati river north of Ahmadabad, Gujarat (W.A. field notes), which are both also part of the ancient Indus river delta (Karpov and Nebolsine 1964). These may also be found to possess *V. flavescens*.

Fig.9 shows all of the definite localities from which *Varanus flavescens* is now known, as well as the expected range. This distribution shows quite clearly that the species is restricted to the rivers of the Indo-gangetic Plain. Thus the species is found in the Indus, Ganges and Brahmaputra rivers and all of their tributaries, except those of the Ganges that are considered "peninsular" (Chambal, Betwa and Ken Rivers, see Mani 1974). Except for the lower deltaic parts of the Ganges—Brahmaputra system, this monitor species seems restricted to the *Khadar* alluvium in the floodplains themselves. Where broad these floodplains are characterized by dead arms, deferred junctions and marshy *jheels*, often several kilometres wide. Near the foothills of the Himalaya, *V. flavescens* seems restricted to the more level areas of finer soil, often covered with marsh and swamp vegetation of the terai, rather than the areas of coarser talus (*bhabar* and *bhur*).

In West Bengal and Bangladesh *V. flavescens* is apparently more widely distributed than in the rest of the Gangetic Plain, where it seems to occur in isolated populations. In Pakistan the distribution is apparently even more spotty, though further collecting may disclose additional localities along major streams in appropriate habitats.

HABITAT

Early in the accumulation of information regarding this species, the notion was developed that *V. flavescens* lived in dry grasslands. This conclusion was undoubtedly fostered by two misconceptions. First, that *V. flavescens* was closely related to *V. exanthematicus*, the African savanna monitor, which does live in xeric habitats. Second, that not all specimens collected and identified as *V. flavescens* were, indeed that species. Some of these were clearly *V. bengalensis*, which is often found in dry habitats (though not optimum). Mertens (1942) had no reason to doubt what had been stated about the habitat of *V. flavescens*, but was puzzled by its flattened tail — usually associated with aquatic species (i.e. *V. salvator*). He concluded that the flattened tail in the former was a retention of that condition, rather than a specialization for the habitat in which it was presumed to live. Rotter (1963) continued the error in an important and the most recent synopsis of the genus, in spite of the fact that Sights (1949) published a good description of the generally wet habitat of *V. flavescens* in West Bengal. In that paper, Sights emphasised the mesic to hydric environment in which he found his specimens—a heavily forested tract with many marshes and brooks.

In 1979 Auffenberg studied the habitat of this species in many places in the Gangetic Plain and during 1986-7 he and the junior authors studied it in several parts of the Indus river. These observations, plus notes available in the Chicago Natural History and Indian Museums (associated with

Fig. 9. Confirmed locality records (dots) for *V. flavescens,* with all major rivers of the Indo-Gangetic plain shown.
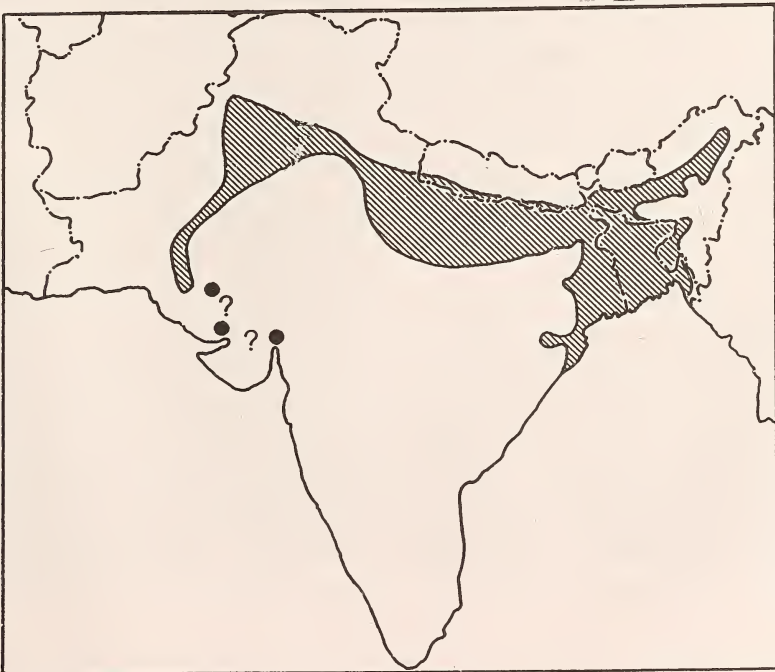

Fig. 10. Probable distribution limits of *V. flavescens* (shaded), with possible extensions in Sind-Gujarat provinces shown.

specimens collected in Orissa and West Bengal), made it clear that *V. flavescens* is primarily a species of marshlands (jheels) in low-lying, sandy areas bordering large rivers and subject to annual flooding. This hydric habitat occurs in almost every locality where the species was observed in the wild. The only exception is along canals associated with rice farming in low-lying areas. For the most part, these rice growing areas were previously partly or completely located within the boundaries of former natural marshlands.

In the meantime, Visser (1985) noted that healthy captives kept under optimum conditions in Europe spent much time in water. Combining these observations with those of Sights (1949), he correctly concluded that the species lived in moist to wet, rather than dry habitats.

The following is a brief list of the major plants found in optimum habitat of *V. flavescens* in northern India; trees include mainly *Dalbergia sissoo, Albizzia procera, Acacia arabica* and *A. catechu*; dominant shrubs are *Tamarix dioca, Zizyphus jujuba, Ehretia laevis* and *Holoptelea integrifolia* grasses. Herbs include *Saccharum spontaneum, S. munja, Phragmites communis* and *Typha elephantina* (or *T. angustata*). In Assam, *Pistia aquatica* and *aldrovanda vesciculosa* are common aquatic plants. Closer to the coast in Bangladesh, West Bengal and Orissa, the tree *Heritiera minor* becomes very common. In Pakistan typical trees in the local habitat include *Populus euphratica* and/or *Acacia nilotica*; dominant shrubs are *Tamarix dioica* and *Zizyphus jujuba*; dominant grasses and herbs are *Phragmites karka, P. communis, Typha augustata* and *Nelumbium* sp. *Varanus flavescens* is not found close to the coast in Pakistan.

In addition, this monitor lizard is often found in and near irrigated fields in both India and Pakistan. Most of the time these are paddy fields, as on Sagar Island, West Bengal, but they may also be maize or mixed crops, as at Charsadda, near Peshawar, Pakistan. In fact, much of the original flood plain habitat throughout the range of this species has been greatly modified by agriculture. In some instances, entire local populations of this lizard have been extirpated in this way. The situation along the Yamuna river near Agra is a good example. The species was first reported from the area by Anderson in 1871. However, no specimens have been found there recently, in spite of the fact that the Agra area is an important source for preserved biological materials used by universities and colleges over much of northern India. Some specimens from the same locality had been deposited in the Indian Museum some time ago (we have confirmed these identifications).

In 1979, 1984, and 1985 the senior author had opportunity to study monitor populations in the Agra area — partly to determine the habitat from which the *V. flavescens* might have originated. Discussions with aged professional animal collectors in the area made it clear that the species was once found near Agra, but only in previously annually inundated lowlands dominated by *Typha*. It is still found (though rare) in similar habitat north of Agra along the Yamuna river, as well as eastward along the main floodplain and tributaries of the Ganges river (common locally). At Dayal bagh, a suburb of Agra, very small, scattered *Typha*—filled lowland areas can still be found. these are small remnants of much larger jheels originally found in the area. Since acquisition of the land by the Rhadasomi community many years ago, most of these jheels have been converted into irrigated paddy fields and the small local populations of *V. flavescens* once present have long ago disappeared.

The same pattern of marshland conversion to paddy has occurred on a massive scale throughout much of the Indo-Gangetic Plain in the past and is responsible for much reduction in range and abundance of this species. This factor, plus the natural long term trend of desertification of at least the western half of the range of this species, and the restriction of marshy areas to flood plains to begin with, accounts for the very spotty distribution of the species at the present time. This distributional pattern is additionally impacted in some areas by a high hunting pressure for its skin. Collectively, these factors lead us to consider

Varanus flavescens as the most endangered of all monitor species on the Asian mainland. What habitat remains is small, and is becoming smaller all the time — particularly in the central to western parts of its range.

In India (West Bengal and Assam only) and Bangladesh, *Varanus flavescens* is sometimes sympatric with both *V. salvator* and *V. bengalensis* (sometimes all three species can be seen in the same marsh). In Pakistan (all provinces in which it occurs) it can be expected to be found in the same habitat with *V. bengalensis*; *V. griseus* is only found in xeric, sandy habitats; it is never syntopic with *V. flavescens* ecologically.

FOOD

Captive *Varanus flavescens* regularly feed upon mice (Auffenberg captives in Florida and Visser 1985) and prepared reptile food (Visser 1985). During this study, evidence of prey was found in 32 individuals (all adult, stomach-pumped in the field or dissected in the laboratory). These remains included frogs, toads, amphibian eggs, reptile eggs (turtles and squamates), birds and their eggs, insects and mammals (all rodents). Because of their advanced state of digestion, species identification were usually not possible.

Forty percent of all prey were frogs (all *Rana* sp.) Toads (all *Bufo stomaticus*) comprised nine percent of the prey. Reptile eggs (turtle and squamate eggs combined) totalled fifteen percent; six percent was mammalian and the same for insects. A few individuals had masses of frogs eggs in the stomach. These were fertilized so that it is clear the eggs had been found in the wild and not the remains of a female frog eaten previously. Feathers were found in only three percent of those that contained prey; bird eggs the same. Thus frogs comprise the most common prey, followed by reptile eggs. Because no scales or other reptile remains were found in the stomachs at the same time we surmise that the eggs were taken from the nests. Many species of monitors are known to feed extensively on reptile eggs so that this is not unexpected in *V. flavescens*.

However, what does seem unusual in the diet reported here is the eating of amphibian eggs. This has not been reported for any other varanid lizard so far. What is also somewhat surprising is that no land or water molluscs are apparently included in the diet, though at least the aquatic viviparid. *Bellamya bengalensis* (*sensu latu*) is common in local shallow marshlands where they could easily be foraged by the monitors. Some other monitor species regularly feed on molluscs (see Auffenberg 1987 for review). Of possible significance is that most of the amphibians found in the gut were taken from individuals collected in September-October; most reptile eggs in February; mammals only in March-April.

GROWTH

No direct information is available on growth of wild individuals. However, *in vitro* staining of bone laminae in wild individuals and data from captivity (Visser 1985) suggest that sexual maturity occurs at about three years. Since mean hatchling SVL is approximately 77 mm and sexual maturity is attained at about 290 mm SVL, the annual estimated SVL growth (if uniform, which it is not) is about 60 mm/year. Because food resources and activity level of the monitors is not uniform throughout the year in view of the seasonal climate of the regions inhabited by the species, growth must be pulsed. The periodicity of this growth pulse can be demonstrated by percent individuals shedding each month.

No individuals were noted shedding their skins from October through December (specimens examined 31). From January through April, seven to twenty percent of all individuals examined (36) were shedding their skins. Shedding becomes much more common from May through September (37), when they represent 37 to 60 percent of the monthly totals examined. Thus we conclude that the least growth is experienced in the fall post-monsoon season, and the highest growth rate during the monsoon season.

Shedding is an indication of growth and as such must occur during and (particularly) after the period of greatest food abundance. If this is the case, then the least food is obtained during the

summer monsoon, for the following period is the one of least evidence of growth. That this is quite probably the case is suggested by the seasonal pattern of fat accumulation (Fig. 4), which shows that the monsoon season is a period of high utilization (degradation) of existing fat in the abdominal cavity in both sexes, rather than a period of accumulation. The lack of growth is perhaps best explained by the low density of food in the habitat, caused by annual monsoonal flooding. this is also reflected in the fact that very few food items were found in the gut during this period. On the other hand, both food contained in the stomach and fat in the abdominal cavity were high during the dry premonsoon period, when most food sources (particularly the most common prey, frogs) would be concentrated in the few small pools of surface water remaining in the habitat. This period of rapid growth is reflected in the high shedding levels noted during the following monsoon period, due to the time lag between food abundance and actual growth and eventual shedding. The entire matter of seasonal growth (amount and lag time) in relation to seasonal variation in food availability deserves attention and would probably handsomely repay investigation in both the laboratory and field.

OTHER REMARKS

As part of a study of the external parasites of all the varanid lizard species of Pakistan, we were surprised to find that while *Varanus bengalensis* adults were regularly and heavily infested with ticks (*Aponoma gervaisi*), no recently caught specimens of *V. flavescens* from India (Varanasi, Fatehbad, Mirzapur) or Pakistan (Dokri, Charsadda, Dina) ever had any ticks, nor possessed any evidence (tick scars) that they had ever been there. This is particularly unusual in view of the fact that in both countries both monitor species can often be found in the same habitat (though local animal catchers and hide hunters claim that they are never found in the same burrows). The only time that ticks were ever found on *V. flavescens* was when the lizards had been kept in the same bag or pen in which *V. bengalensis* had recently been kept.

At such times when ticks were found on *V. flavescens* we noted that tick distribution on the host was not typical of the pattern regularly found on *V. bengalensis* (W.A. field notes, see Auffenberg 1987 for data on tick site attachment on other varanid species hosts).

No studies have yet been completed on the internal parasites of this species, though appropriate material has been collected and is now in the hands of specialists in such matters. Nematode parasites are being investigated by workers in Pakistan. Dr S. Telford, Florida State Museum, is currently studying blood parasites of *V. flavescens* caught near Dokri, Pakistan. This material proves that this monitor is often infested with a blood parasite (probably malarial) that is not found in either *Varanus griseus* nor *V. bengalensis* in any part of their geographic ranges (Dr Telford will report his results separately when his studies are completed).

Thus what little is known about the parasites of *Varanus flavescens* suggests a very different picture from that reported or known to exist in other Indo-Pakistan monitors. These data further substantiate the presumably isolated phylogenetic position of *V. flavescens* based on studies of blood chemistry, penial morphology and karyotypes as indicated above.

Compared to other varanids in which injuries were studied (Auffenberg 1981, 1987), *Varanus flavescens* shows remarkably few scars, even when compared with *V. bengalensis* from the same habitat in Pakistan. There is no consistently scarred area(s) caused during combat, feeding, or in shelters, as in the other species studied. Though snipped-off tail tips are common in other species, this occurred only once (a male) in 87 *V. flavescens* examined for this character in Pakistan. Of 38 *V. bengalensis* from the same habitat in Pakistan, 26% (7 males, 2 females) had the tail snipped off. Tail injuries in *V. komodoensis* are usually due to courtship by the males (Auffenberg 1981). This may also be the case in *V. bengalensis*, since more females than males have the tail tip snipped off. The absence of such injuries on the tail of *V. flavescens* suggests that the courtship pattern in

this species does not involve much biting by the males, or at least not on the tail.

A necrotic liver was noted in one adult from India; an ovarian tumour in another individual from Pakistan.

The pH of the empty stomach was tested in three individuals; it ranged from 2.2–2.9, X = 2.5

d'Abreu (1932) states that during the dry season this species takes refuge in large cracks in the earth. While this may be an accurate description, the species also digs burrows in which it spends the night and the cooler weather of the winter months. It may also use such burrows for aestivation during particularly dry periods. Pakistani tribals very experienced with this animal claim that, unlike *V. bengalensis* and *V. griseus*, it often closes the mouth of its burrow at night. We were not, unfortunatley, able to verify this. If true, it seems to be the only species of monitor lizard that does so.

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